Advanced Virgo - IME
IRC Report

Infrastructure modifications: proposed strategy for noise reduction

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2 Subsystem overview

The IME subsystem (Infrastructure Modifications for Environmental noise reduction) concerns all the hard works aimed to reduce the level of anthropogenic noise into the experimental buildings. The main tasks of IME will be: the replacement of the machines with more silent ones and, if needed, their displacement out of the experimental halls; the improvement of the insulation performances of the air flow distribution systems; the realization of adequate acoustically insulated rooms to displace the noisy electronics (or part of it). The subsystem will also be involved in minor tasks such as the support in the realization of the eventual infrastructural works needed for the installation of the deliverables of the other subsystems.

3 Peculiarity of the IME subsystem

In order to better understand the specificity and peculiarity of the IME subsystem design with respect to the other subsystems, a few preliminary considerations have to be made.

First of all it has to be considered that, in general, when we approach the design of civil engineering works, we first establish the basic requirements of the works to be realized and then we develop the various design options to meet such requirements.

With respect to the IME project, the basic requirements are difficult to fix since the scope of the project - the environmental noise mitigation - is to be evaluated not with a view of complying with general standards or official laws, but with the future AdV interferometer sensitivity. As a consequence also cost-benefits analyses are very hard to perform.

Secondly, an important role in defining IME subsystem design requirements will be played by the result of Virgo+ environmental noise mitigation activity.

As of today, the environmental noise hunting activity has individuated most relevant sources (the noise-inducing machines) of seismic, acoustic and electro-magnetic noise and some major noise coupling paths to the interferometer. These coupling noises are expected to be a limiting factor for Virgo+, and a few ad-hoc and low impact infrastructure modification works aimed at mitigating the noise effects have already been scheduled for Virgo+ commissioning phase.

A preliminary evaluation of the works performed seems to be encouraging, however part of the works are not completed yet and other are still under investigation. The effectiveness of such mitigation campaign has to be evaluated when all the works will be completed.

In this framework it has to be noted that the results expected from Virgo+ mitigation works can only represent a projection of the present noises on the AdV sensitivity. Considering the large amount of noises produced to the interferometer by the above mentioned sources (as better specified in the following sections of this document), we should avoid to face the possibility that not yet evidenced noise coupling could affect the AdV interferometer in the new most sensitive configuration.

A further reason of uncertainty in defining IME design requirements is then represented by the fact that as of today there are still important design solutions that could be envisaged by other subsystems/Virgo groups in relation to the AdV project, such as the thermal stability of the towers and the electric power DC distribution for the experimental halls apparatus. The implementation of such solutions would significantly affect the definition of requirements and the specifications of the air conditioning systems (HVAC systems) and the electrical power systems for AdV and, consequently, the strategy to adopt in order to reduce environmental noises.

In light of the above, at present the IME subsystem keeps open all possible strategies to approach the problem of noise mitigation and so the design questions concerning the infrastructure modification works for the reduction of the environmental noises.

The designed solutions proposed for AdV are still in a preliminary phase and mainly based on the experiences gained with regard to Virgo systems operation, the rules quoted in literature and qualitative considerations.

Therefore, the hypotheses evaluated are based on the “principle of care”. Given the heavy impact on the interferometer of the civil engineering modification works and the uncertainties of their effective mitigation effects, it is necessary to take into account significant safety margins.

Interventions “a posteriori” to be realized during the commission phase of AdV are generally more expensive, difficult to implement and require the stop of the scientific activity.
Finally, as further point of uncertainty, we have to consider that studies of alternative strategies for tackling environmental noise and its coupling to the interferometer have started (modification of the support systems of the in-air optical benches. However the results will be hardly available before the AdV project approval; besides, such alternative strategies will inevitably need other infrastructure modification works.
In conclusion it has to be mentioned that the IME subsystem will be involved also in generic works as support to the other subsystems, which are not directly related to the noise mitigation, but inevitable. Such works will concern the realization of the infrastructural works needed for the installation of the deliverables of the other subsystems (i.e. modification works of the power systems to install equipments, realization of the external basements of the LN_2 tanks for the cryotraps, etc.) and their impact has been considered in the drawing up of the preliminary evaluation of costs, manpower need and planning.

4 The noise hunting activities so far

4.1 Introduction

During V/V+ commissioning the noise-inducing machines has been identified and several progresses have been made about the understanding of the coupling mechanisms between such noises and the interferometer. The description of such activities, also reporting the explanation of the main results achieved on ITF sensitivity, is provided in [1].
In order to mitigate the environmental noises several infrastructure works have been performed during V/V+ commissioning.
A description of these actions is reported in [2] where are detailed, for each work, the motivation, the noise mitigation achieved, the limitations/side effects (if presents) and the residual noise. The list in the following paragraph summarizes these mitigation works and reports the main results achieved. It also reports the foreseen/useful works to be done before VSR2.

4.2 Works performed/planned for the noise mitigation actions

Here below a list concerning the improvements works performed/planned so far.

nr.	item	date	notes
1	Acoustic enclosures in LL	Sep 2006	Not good insulation from CB hall. Results achieved above 100 Hz.
2	Acoustic enclosure for DL	Apr 2007	Results achieved above 100 Hz but none or poor below.
3	Acoustic enclosures for NEB optical bench	May 2007	Results achieved above 100 Hz but none or poor below.
4	Acoustic enclosures for WEB optical bench	May 2007	Results achieved above 100 Hz but none or poor below.
5	Installation of rubber bellow in the cold water pipeline to mitigate CB pump 1 noise	Dec 2007	Result not much effective
6	Installation of acoustic panels on the DAQ windows	Gen 2008	Results achieved above 100 Hz
7	Relocation of the DAQ HVAC machine	Feb-Mar 2008	Reduction of noise in DL in the 50-150 Hz band.

nr.	item	date	notes
8	Realization of the EE Room (acoustic separating wall, door and cooling system) to host LL electronic racks	Jul 2008; Feb 2009	Good acoustic insulation of the room with respect to the hall and LL. Acoustic noise in LL reduced above few hundred Hz.
9	Modification of the CB HVAC machine air flow	Sep-Oct 2008	Reduction of noise in DL in the 0-20 Hz band.
10	Improvement works on the CB electrical systems distribution	Jun-Oct 2008	Electromagnetic noise gains (TBC)
11	Mitigation of electromagnetic noise due to inductance loops in the fluorescent lighting of the CB mechanical lab	Jul 2008	Noise detected and eliminated by re-cabling of the circuits.
12	Electromagnetic noise coming from the MC HVAC resistive heating	Jul 2008	Noise detected. The cure needs the installation of alternative system.
13	Electromagnetic noise coming from the fluorescent lighting of the EE Room	Feb2009	Noise detected and eliminated by substitution of the equipments.
14	Improvements on separating walls in the end technical buildings	TBD	It would be useful to perform before VSR2.
15	Separation of the LL HVAV system from the CR's one	TBD	It would be useful to perform before VSR2.
16	Installation of dampers for electric motors and fans of the CB HVAC machine	TBD	It would be useful to perform before VSR2.
17	Modification works of the cold water pipeline to eliminate CB pump 1	TBD	It would be useful to perform before VSR2.
18	Reduction of the NEB HVAC machine air flow	TBD	Unlikely to perform, due to the improvements already achieved at NE with mirror change.
19	Reduction of the WEB HVAC machine air flow	TBD	It would be useful to perform before VSR2.

5 Possible solutions for the infrastructure upgrades

The infrastructure upgrades were framed in [3] considering two solutions, named "*reference solution*" and "*further upgrades*". The difference between these two scenarios concerns only the End Buildings. Even though this framework remains still valid, at present we are developing the interventions considered more effective for each experimental building, trying to establish a priority scale among the foreseen interventions.

5.1 High-priority interventions

In light of the above mentioned statements, the most important infrastructure upgrades to be realized for each experimental building are described in the following.

- The optimization of the HVAC equipments, both for the acoustic and the seismic performances, through:
  - the realization of independent platforms for the machines to mitigate noise transmission;
  - the suspension of the machines on adequate anti-vibrating supports;
  - the installation of damping joints for the water pipes;
  - the improvement of the air flow distribution by optimization of the air conditioning machines (air fans balancing, installation of more noiseless machines) and by the replacement of the air ducts with ones provided with more phono-absorbing characteristics.
  - the seismic isolation of the air ducts from the walls by adequate supports and from the HVAC machines by flexible joints;
  - the improvement of the air ducts noise inducing parts (curves, links, etc.) and the installation of proper air ducts silencers.

A further important evaluation about the need of replacement of the HVAC machines has to be done also taking into account of the obsolescence of the current machines. In fact these machines will come to 15÷20 years 24/24h running time at the expected period of the AdV operation, no longer guarantee an acceptable operation in terms of efficiency and reliability.

- The displacement of the electronics racks in ad hoc spaces (Electronics Equipments Room - EE Room). Such action concerns the realization of dedicated acoustic enclosures or the improvement of the acoustic isolation of the existing structures. These spaces are necessary, even though they may be reduced, in case the electronics racks are kept in the current positions and their cooling systems are modified. In such case the enclosures can be used to accommodate only the power supplies and the AC/DC converters. Such actions will be effective also for the mitigation of the electromagnetic noise coming from these sources.

- The displacement of the electromagnetic noise sources as far as possible from the towers, if such noisy equipments cannot be displaced in the suitable EE Rooms.

As general consideration, it has to be noted that the proposal of the displacement of the electronics depends on choices/strategies to be done by other subsystems/Virgo groups. Therefore, the exact impact of the relevant infrastructure works will be fixed after such choices.

The above described interventions are detailed for each building in the following.

Central Building - It is foreseen the realization of a new external technical area of about 150 m^2, on the east side of the Central Building (CB), to install the air handler machines (for the CB hall, the Clean Rooms and the EE Rooms) and the relevant equipments (manifolds, water pumps). The foundation supporting the machines will be ground isolated by an appropriate damping system or a sand layer, while the machines will be set on damping pads. New water pipelines to link the machines to the Technical Building will be realized (Fig. 1, 2, 3 and 4). Other improvements concern the realization of a separate HVAC system for the Laser Lab, not connected with the Clean Rooms one. Finally it has been considered the realization of an EE Room hosting the electronics racks (suspensions and vacuum). This new EE Room can be realized in two unused offices (CB - level 2). For this scope we need to improve the acoustic isolation of the concrete-floors and the walls; moreover we have to realize a dedicated HVAC system.

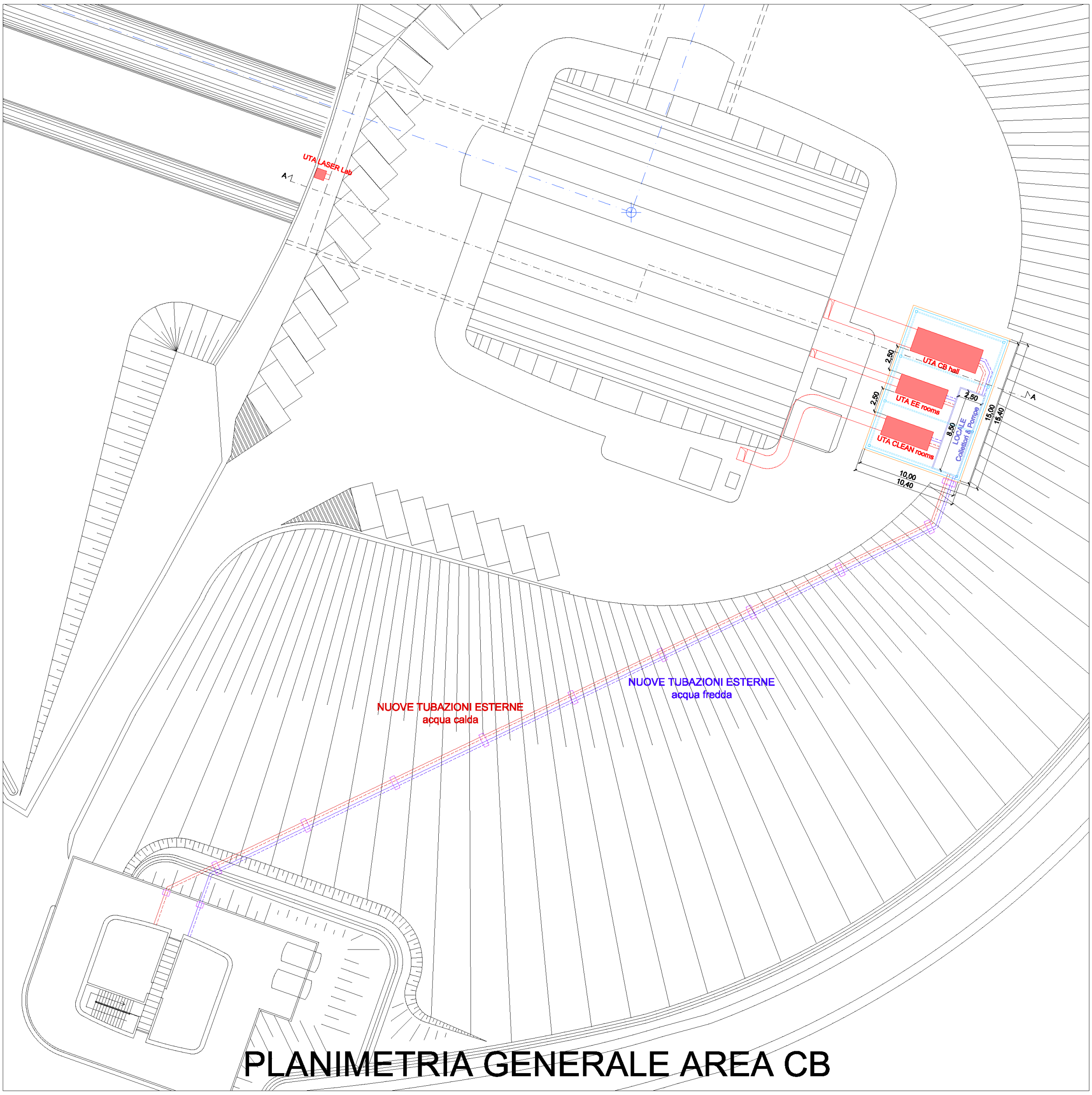

Fig. 1 – Layout of the Central Area with the new CB external technical area

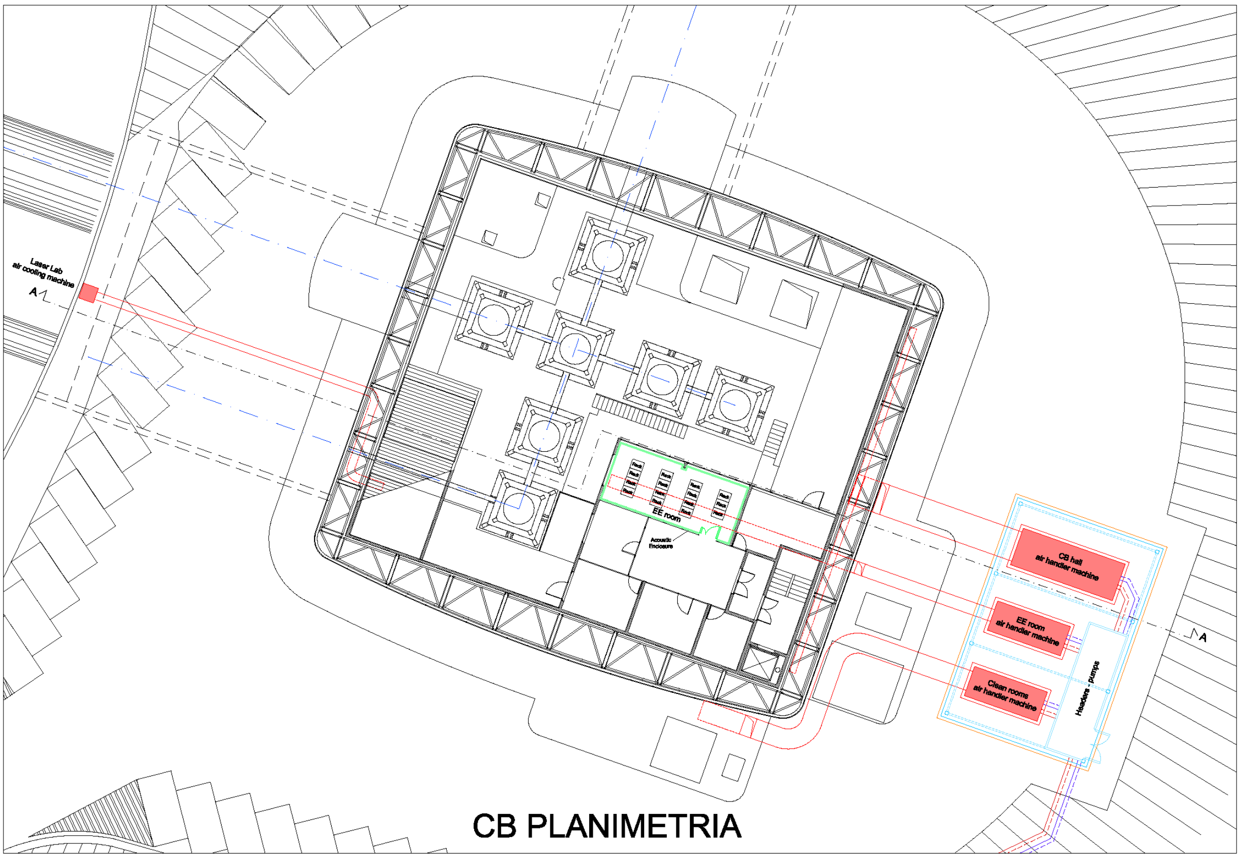

Fig. 2 – Plan view of the CB

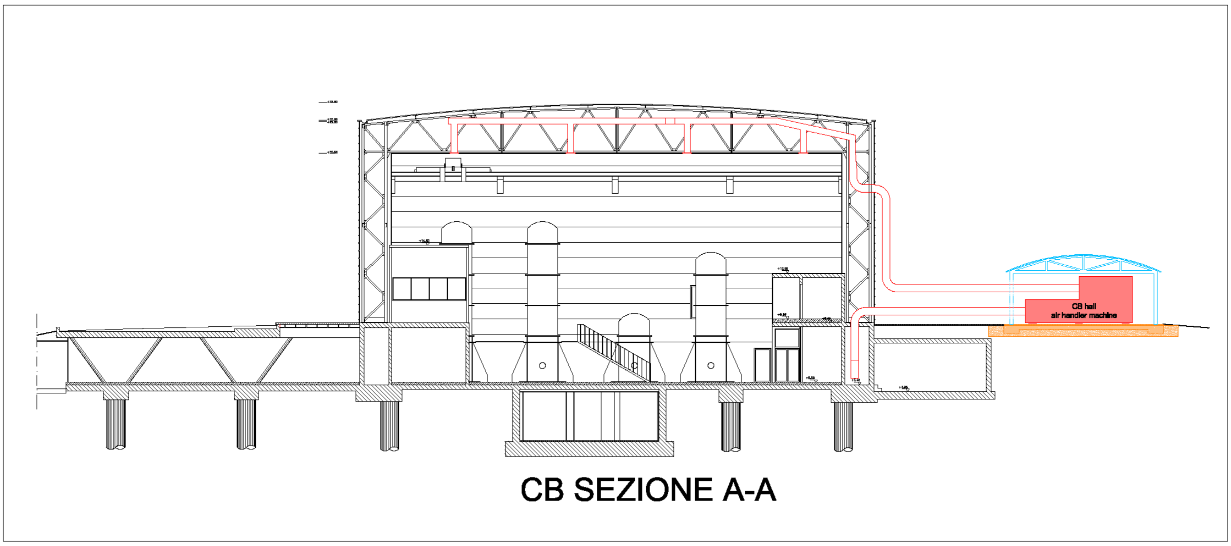

Fig. 3 – Cross section of the CB

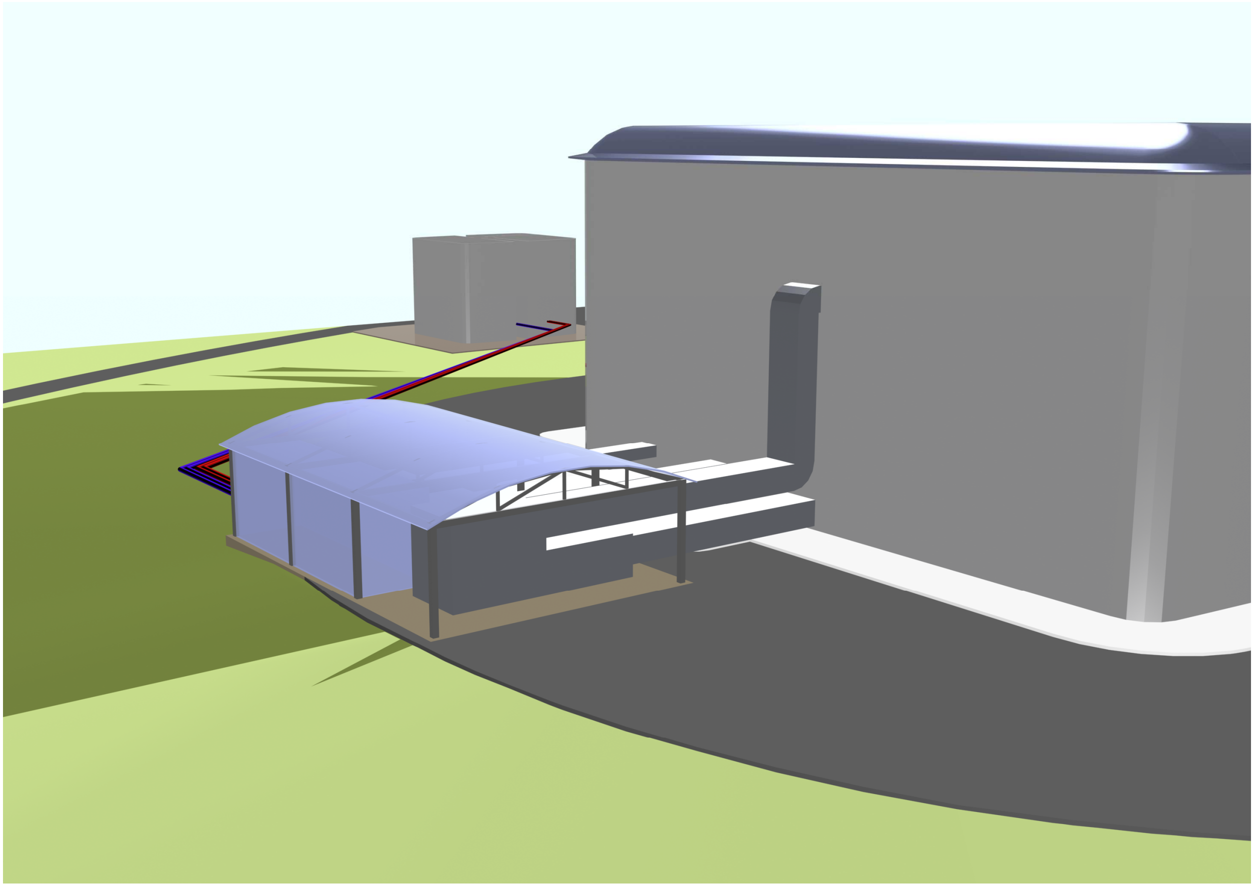

Fig. 4 – Perspective view of the Central Area with the new CB external technical area

Mode Cleaner Building - For this building we considered the realization of an external technical area of about 25 m^2, on the west side of the building, with the same characteristics of the CB, to install the chillers (heat pumps) and the air handler machine (Fig. 5 and 6). Moreover it has been foreseen the realization of an appropriate acoustic enclosure hosting the electronics racks (suspensions and vacuum). For the electronics the same recovery actions as for the CB can be applied.

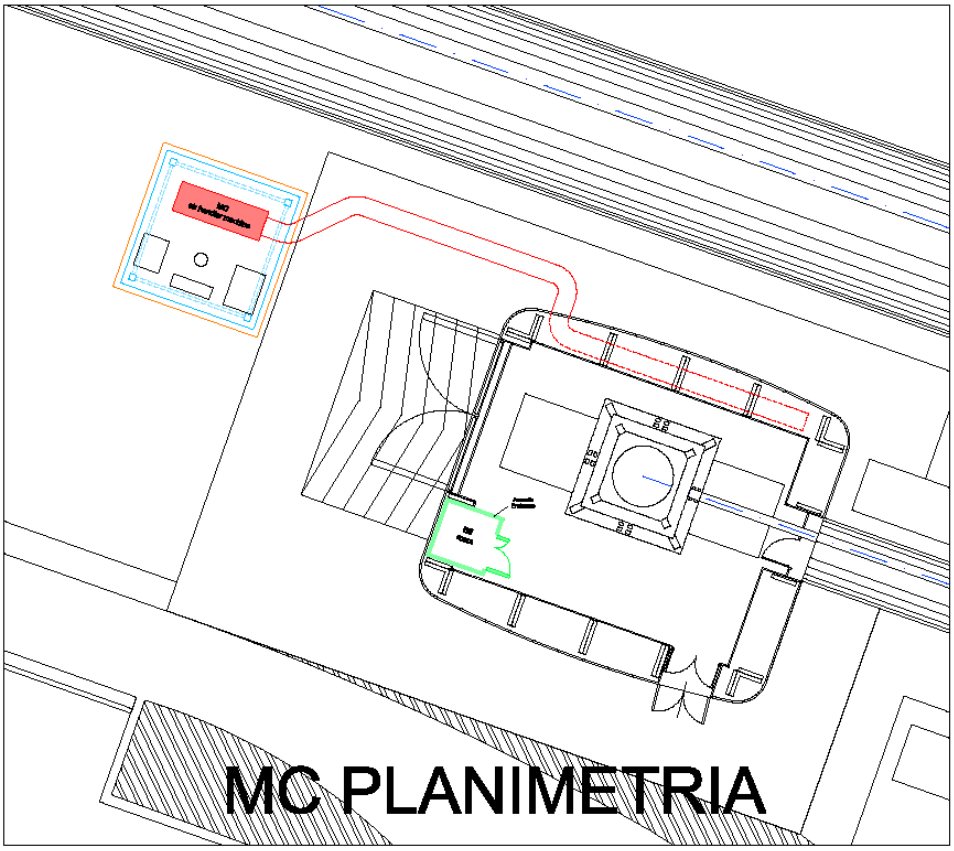

Fig. 5 – Plan view of the CB

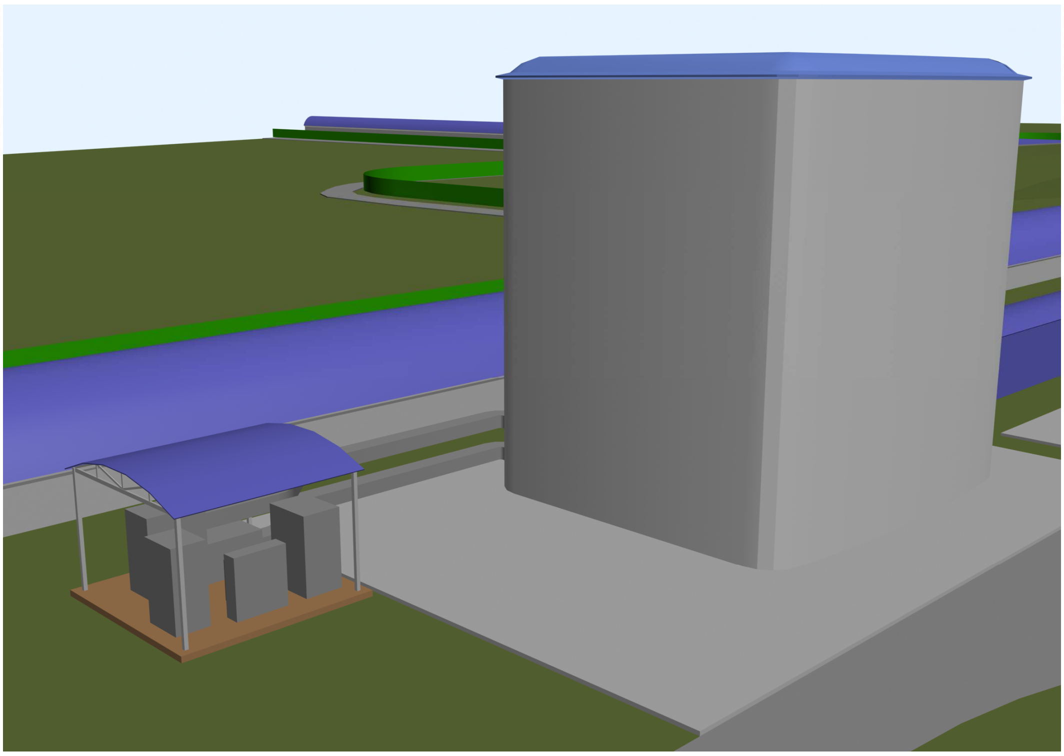

Fig. 6 – Perspective view of the MC

End Buildings - In this case the air handler machine might be kept in the current position. In fact the floor of the technical building and the foundation of the tower are already independent by structural joints. Anyway, we considered the realization of a structural joint between the foundation supporting the machine and the remaining part of the room. The machine will be set on damping pads and, if needed, the foundation might be rebuilt and ground isolated by a specific damping system or an appropriate sand layer. All the other machines (the heat generator, the air compressor and the electric machines) will remain in their current position, considering that as a sufficient distance. Even for these buildings the realization of an acoustic enclosure hosting the electronics racks (suspensions and vacuum) has been considered.

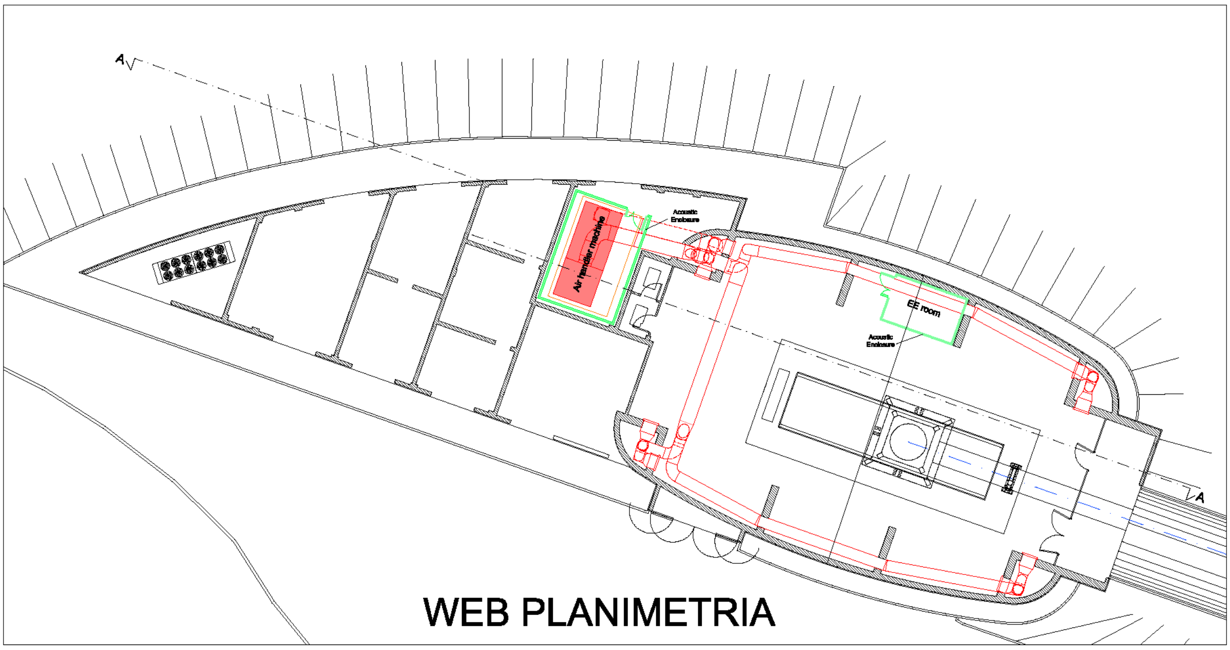

Fig. 7 – Plan view of the WEB

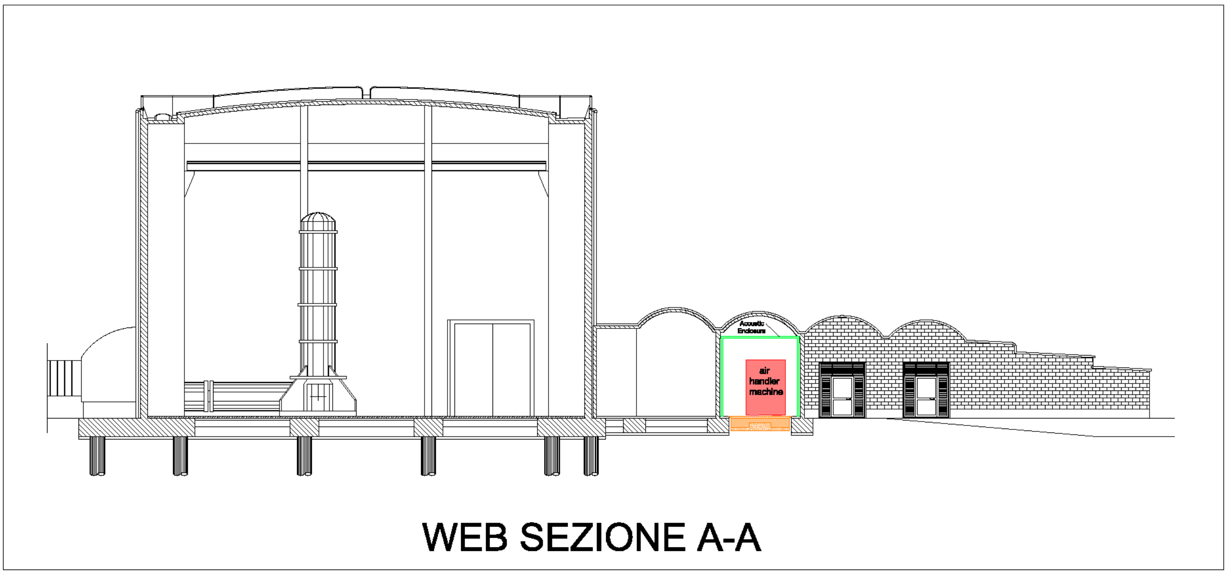

Fig. 8 – Cross section of the WEB

5.2 Other possible interventions

A further grade of intervention in view of the environmental noise mitigation for the End Buildings could be developed on the hypothesis of realizing a new separated technical area also, as already described as reference solution for the other experimental buildings. These facilities will have the same technical solutions and characteristics of the CB's one. The estimated surface could be of about 150 m^2, in order to accommodate both the air handler machine and the relevant equipments (tanks, water pumps) as well as the other potential noisy machines (the heat generator, the air compressor, the electric power generator, the transformer and the UPS machine). However in this case various intermediate solutions are possible, such as displacing only a part of the machines in the new area and moving the remaining part in the existing technical building.
Anyway, at present, such scenario seems unlikely, since first measurements showed the displacement of the electric power machines not necessary, while the improvements of the HVAC mitigation works foreseen with the previous solution could be sufficient.

Other possible infrastructure mitigation works could concern the installation of proper phono-absorbing elements in the ceiling and the walls of each experimental hall in order to reduce the high value of their reverberation time. However the need of such works has to be carefully evaluated for their large impact and the possible side effects, as the worsening of the cleaning conditions of the experimental halls.

6 Costs

The following table shows a rough cost evaluation since a more precise evaluation requires detailed designs and performance of accurate modeling analyses.

nr.	item	cost k€ (20% tax included)
1	HVAC air handler relocation	708
2	HVAC air distribution	240
3	Electronic relocation	228
4	Halls acoustic damping	210
5	Support works to the other Subsystems	210
	Total	**1596**

The cost estimation will be updated and as much as possible detailed in the next version of this document.

7 Manpower

References

[1] I.Fiori, "Environmental noises during Virgo and Virgo+ commissioning".
[2] I.Fiori, "Infrastructure works for mitigation of environmental noises during Virgo and Virgo+ commissioning".
[3] VIR-089A-08, "Advanced Virgo Preliminary Design".